# AIR TRAFFIC MANAGEMENT MOVES INTO THE 21ST CENTURY

*Learn about the major changes in concepts and technology that will soon make flying safer and more economical.*

BILL SIURU

By the year 2005, the number of commercial passengers flying in the U.S. will increase by almost 45%—from about 625 to some 900 million annually. To meet that increased demand, as well as to modernize equipment that often dates back to the 1960s and, in some cases, even the 1950s, the Federal Aviation Administration (FAA) will be making major changes in the Air Traffic Management system.

The Air Traffic Management (ATM) system is designed to ensure the safe and efficient flight of aircraft flying under instrument flight rules (IFR). It is responsible for the aircraft's safety from takeoff to landing. That responsibility is divided into three controlled airspaces—airport, terminal, and en route (see Fig. 1). At the busiest airports, the airport airspace as well as the airport's surface traffic is supervised by the control tower. Beyond the airport airspace, while flying in terminal airspace, aircraft are supervised by Terminal Radar Approach Control (TRACON). The en route airspace, where aircraft spend most of their flying time, is supervised by an Air Route Traffic Control Center (ARTCC). ATM modernization will affect all aspects of the IFR flight—communications, navigation, surveillance and ATM automation.

**Communications.** Currently, air-ground communications uses mostly voice on the VHF and HF bands, and is pretty much limited to flight-plan changes, aircraft separation and sequence instructions, weather, and advisories on other aircraft flying under visual flight rules (VFR) in the area. Communications between adjacent air-traffic service locations is by landline (telephone) using voice and a limited amount of data transmission.

One example of modernization already underway is the Voice Switching and Control System (VSCS) to replace 1950s electromechanical

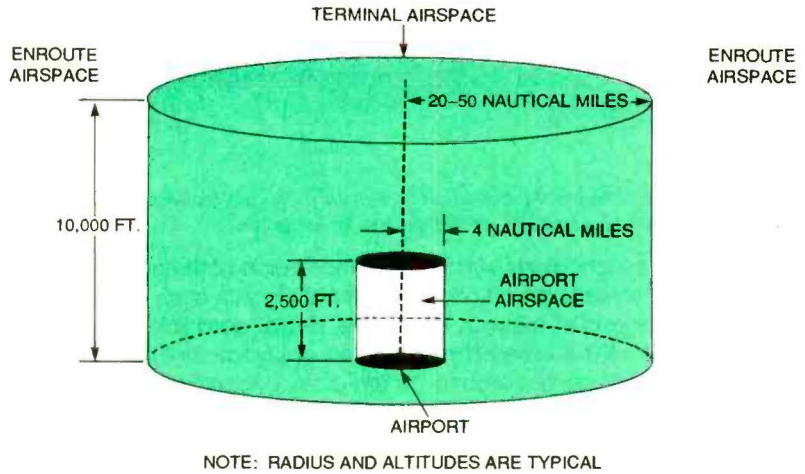


*Fig. 1. The airspace over the U.S. is divided into three regions—airport, terminal, and en route. Most of an aircraft's flight occurs in the en route region.*



www.americanradiohistory.com

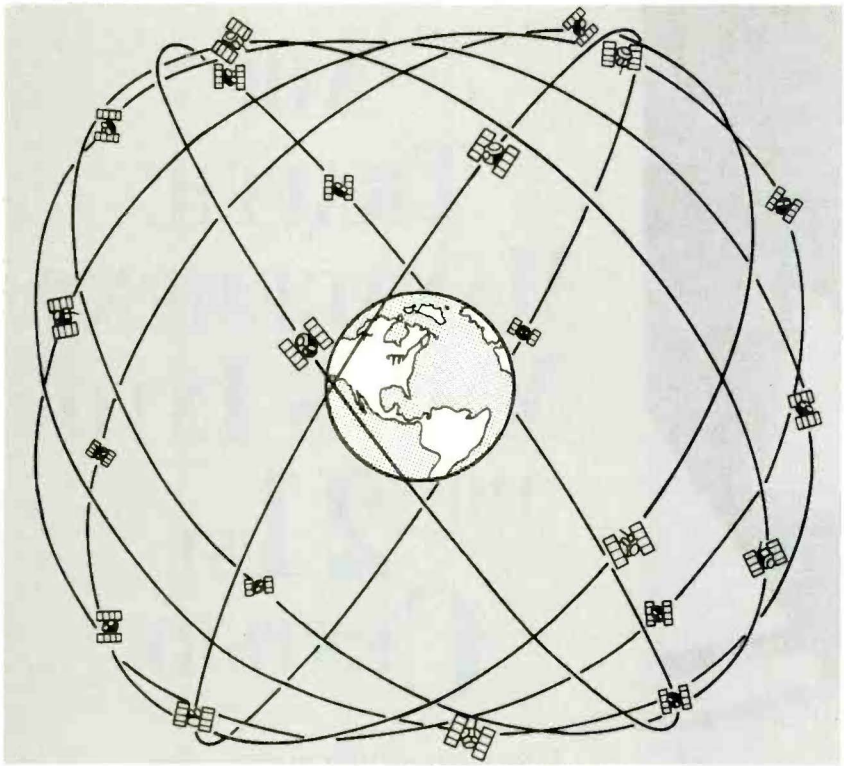

*Fig. 2. Each of the 24 GPS satellite are placed in an orbit where they circle the earth every 12 hours. Four GPS satellites are located in each of six orbital planes inclined at 55 degrees to the equator.*

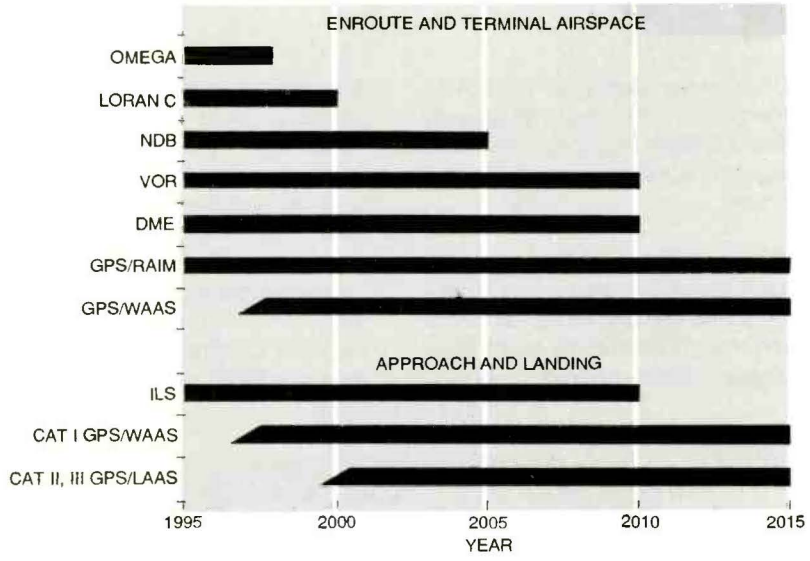


*Fig. 3. This chart illustrates the transition from traditional navigational systems such as Loran C to ones based on GPS and other new technologies.*

and vacuum-tube technology with fiber-optics, touch screens, and digital electronics. By the end of this year, a total of 21 VSCSs will be installed at ATC (air-traffic control) centers around the country. VSCS virtually eliminates delays and allows controllers to adjust their communications system to meet the changing traffic volume, weather conditions, and workload.

Since voice communications is not compatible with automated ATM systems, digital data links that let computers easily talk to other computers are a must. For example, future communications will also take place using two-way, high-speed Gatelink data communications links while a plane is parked on the ground, and communication satellites while in the air. Voice communications will still be available for backup and for emergencies and problem resolution.

**Navigation.** Over the next few years, systems such as Omega, Loran C, NDB (non-directional beacons), VOR-DME (VHF omnidirectional range distance-measuring equipment), and ILS (instrument-landing systems) so familiar to pilots will be retired (see Fig. 3). Thousands of those ground-based systems, some dating back a half century, will be replaced by Global Positioning System (GPS) navigation satellites, communication satellites, and far fewer ground sites.

Radio navigation requires four qualities—accuracy, integrity, availability, and continuity of service. *Accuracy,* expressed in statistical terms such as 100 meters 95% of the time, indicates the maximum difference between the estimated and actual position. *Integrity* refers to the ability to provide a timely warning when the GPS signal is not accurate and should not be used. *Availability* means there is a sufficient number of GPS signals for accurate position determination. *Continuity of service* is the ability to provide enough GPS signals over a specified period of time without interruption.

Civilian GPS users can pinpoint their location with an accuracy of 100 meters horizontally and 156 meters vertically 95% of the time. In most cases that is not quite sufficient for aviation and must be augmented by other techniques. The increased accuracy available to the military—22 meters horizontally and 28 meters vertically with 95% confidence—is not available to civilian users since the U.S. logically wants to deny that accuracy to an enemy.

The 24 Global Position System satellites (see Fig. 2) represent just the first phase of the Global Navigation Satellite System (GNSS), an international system that will also include 24 Russian navigation satellites, known as the GLONASS series. With 19 of the satellites already launched at the time this was written, that 24-satellite constellation should be complete shortly.

Because of low traffic density on routes over the Atlantic and Pacific oceans, the information from the basic Global Positioning system only requires augmentation with Receiver



www.americanradiohistory.com

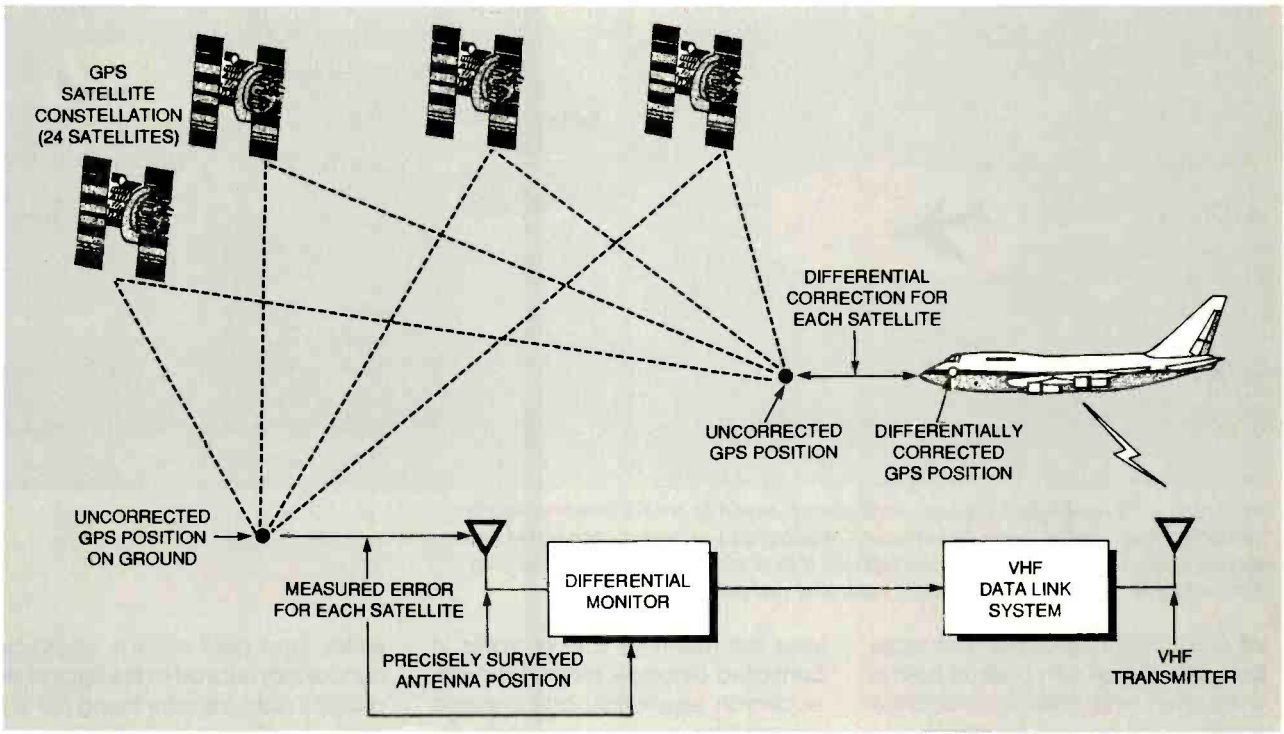


*Fig. 4. The differential GPS correction is computed from signals received by a precisely located ground receiver and then transmitted to the aircraft so the same correction can be made there as well.*

Autonomous Integrity Monitoring (RAIM), which is incorporated into the aircraft's GPS receiver. By continuously monitoring the integrity of the received GPS signals, RAIM informs the flight crew as to whether or not they can reply on the GPS signal. With the forecasted wide-spread use of GPS, the U.S. plans to discontinue supporting the ground-based Omega and Loran C radio navigation systems.

The much higher traffic density in the en route and terminal airspace over the U.S. mainland requires greater capability than provided by GPS/RAIM. That requirement will be fulfilled by the Wide Area Augmentation System (WAAS), which will use 20–30 ground stations, GPS, and several communication satellites in geostationary orbit. The ground sites will monitor the radio navigation signals transmitted by GPS, and that data will be relayed to an aircraft via a communications satellite. When in operation in late 1997 or early 1998, WAAS coverage will extend over the entire U.S., as well as the U.S.-managed airspace over the Atlantic and Pacific oceans. Current plans call for an eventual phase out of non-directional beacons and VHF omnidirectional range distance-measuring equipment ground sites now in use.

WAAS will also be used for non-precision and Category I (more on that in a moment) ILS approaches and landings, starting at some airports in late 1997 or early 1998. One of the most challenging tasks for GPS will be using it during precision approaches and landings under poor visibility conditions.

There are three categories of precision landings—Category I, II and III—each with decreasing visibility and thus tighter requirements on accuracy. Precision approaches now use a three-dimensional (horizontal and vertical) glide path provided by an ILS. That enables the aircraft both to align itself with a runway and to fly along a 3-degree glide path with respect to the runway surface.

A second GPS-based system, Local Area Augmentation System (LAAS) will be used for Category I approaches at a few airports without WAAS coverage. More significant, LAAS will replace ILS for Category II and III precision approaches, and thus ILS could be entirely gone by 2010.

The disadvantage of LAAS over WAAS is that LAAS provides coverage in the airspace only in the immediate vicinity of a single airport. That means far more ground sites, so LAAS is more expensive to build and operate. While LAAS performs with the same level of capability as ILS, a single LAAS can provide assistance for several runways at an airport. An ILS has to be placed at the end of each runway.

While the basic civil version of GPS has sufficient accuracy for en route and terminal airspace navigation, it is not sufficiently accurate for precision approaches and landings. Therefore Differential GPS has been developed to increase accuracies to about one meter.

Differential GPS (see Fig. 4) uses a ground receiver whose fixed location is precisely known. That ground unit receives the radio navigation signals from the same GPS satellites as the aircraft. Since that ground receiver's location is precisely known, the difference, or correction, between the exact location and the location computed from GPS signals can be determined. That correction is instantaneously transmitted to the aircraft so the same correction can be made aboard it.

**Surveillance.** While control-tower personnel usually observe the aircraft they are controlling, at the busier airports they also have radar displays for poor visibility conditions. Controllers manage both the minimum horizon-



www.americanradiohistory.com

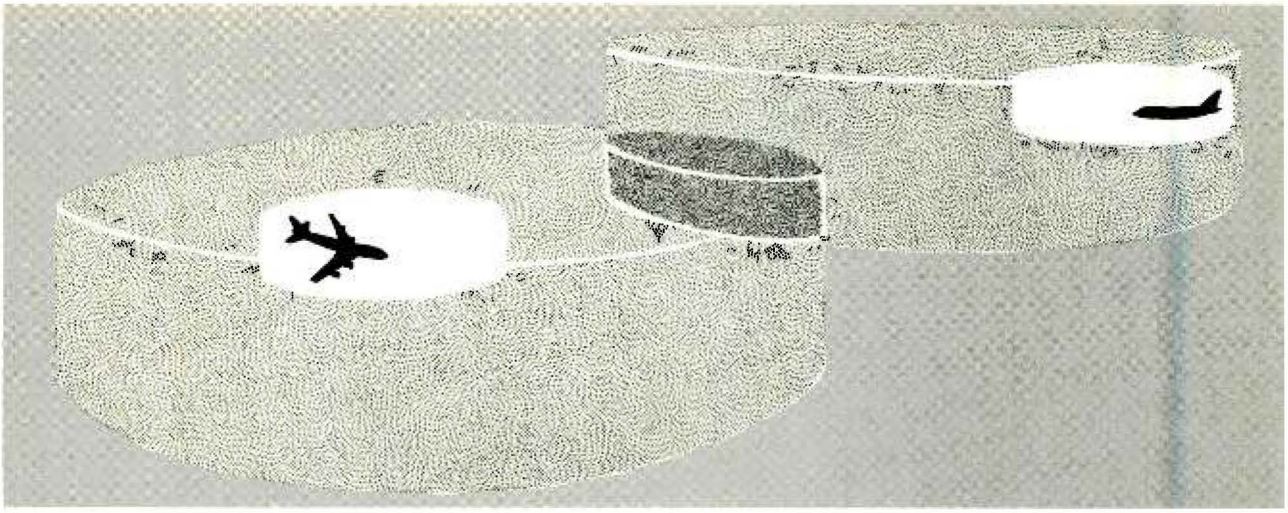

*Fig. 5. In the "Free Flight" concept, each aircraft would fly within zones—a smaller "protected zone" and a larger "alert zone." An aircraft's protected zone would never meet the protected zone of another aircraft and if their alert zones make contact, an alert calling for action by the air-traffic controller and pilot is signaled.*

tal and vertical separation distances between aircraft with backup from a traffic alert and collision avoidance system found now on virtually all carrier aircraft. TRACONs (terminal radar-approach control) or ARTCCs (air-route traffic control center) currently use a combination of primary and secondary radars to locate and track aircraft flying IFR in terminal and en route airspace. Primary radars, also called search radars, use passive electromagnetic reflections from the aircraft to monitor their location a horizontal plane. Secondary radars actively interrogate aircraft equipped with beacon transponders to determine their horizontal position as well as their altitude and identity.

By the turn of the century, primary radars used to keep track of aircraft in en route will be phased out and their function replaced by Automatic Dependent Surveillance (ADS). By 2011, ADS will provide aircraft position data now provided by both primary and secondary radars in en route and terminal airspace. Rather than being tracked by ground-based radar, with ADS, each aircraft's navigation system transmits its position determined from the GPS every few seconds via a digital data link to the appropriate ATC facility. Terminal primary radars and all secondary radars would still be retained as a backup to ADS.

**ATM Automation.** The ATM mission consists of tactical air-traffic control and strategic traffic-flow management (TFM). Air-traffic control supervises the real-time flow of traffic in controlled airspace, maintains proper aircraft separation, and prevents aircraft from crashing into obstacles or the ground. Traffic-flow management is responsible for the optimal, smooth flow of all IFR air traffic around major airports and in high-density controlled airspace. The ATC System Command Center (ATCSCC) located near Washington, D.C. manages the overall flow of IFR aircraft over the continental U.S.

By 2011 the FAA will have upgraded or replaced the existing ATM software, automation equipment, and displays throughout the entire system, including ARTCCs, TRACONs, and the ATCSCC. Automation is required to handle the huge increase in air traffic while maintaining, or, hopefully, improving safety. Automation coupled with data-link communications will also allow a "control by exception" philosophy. Controllers would take action only if an aircraft is in conflict with another aircraft, diverting from its flight plan, or in emergency and abnormal situations. Otherwise, routine flights will occur automatically with little input from controllers. Control by exception is the basis of the "Free Flight" concept, which we will discuss in a moment.

One example of future automation is where crews could monitor the weather continually on cockpit displays while en route. The weather data from the National Weather Service and the FAA from ground-based observations, weather radars and satellites, and pilot reports would be periodically relayed to the aircraft via a digital data link after being put in a easily used format to be displayed on a graphic cockpit display.

**Free Flight.** Most air traffic in the U.S. is general-aviation aircraft flying VFR below 18,000 feet. They fly wherever and whenever they want, weather permitting, as long as they do not fly into airspace reserved for IFR aircraft or special-use airspace such as that reserved for the military. Free Flight, as being developed by the FAA in collaboration with the airline and aviation communities, means almost as much flexibility for aircraft flying IFR.

With Free Flight, two zones would encircle each IFR aircraft (see Fig. 5). The size would depend on the aircraft's speed and performance, as well as the capability of its onboard CNS (communications, navigation, surveillance) equipment. The greater the capability, the larger the zone. The smaller "protected zone" of one aircraft can never intersect the protected zone of another aircraft. The significantly larger "alert zone" extends beyond the protected zone. Aircraft maneuver at will until one aircraft's alert zone contacts another's alert zone. That sets off a "control-by-exception" situation requiring action such as the air-traffic controller providing one or both pilots with course corrections or restrictions to ensure separation.

Currently, IFR pilots must get pre-ap-

*(Continued on page 54)*



www.americanradiohistory.com

## AIR TRAFFIC MANAGEMENT

*(Continued from page 46)*

proval from the air-traffic controller for deviations from their flight plans. With Free Flight, the pilot will choose the route, speed, and altitude in real time and then notify the air controller of the plan. The pilot's flexibility will be restricted only as needed to ensure separation and safety, prevent entry into special-use airspace, or when traffic density at busy airports or in congested airspace precludes flying under Free Flight rules. For the bulk of an IFR flight, pilots would have the same freedom as a pilot flying VFR in terms of course, speed, and altitude selection.

The FAA would continue to monitor congested airspace and major airports operating near their capacity to ensure aircraft density does not exceed a safe level. When capacity is approached, Free Flight rules would be temporarily suspended and more structured traffic flow of would be imposed. To better anticipate where and when traffic density would exceed safe Free Flight levels, a historical database on hourly, daily, and monthly airspace-density patterns would be developed.

With Free Flight, aircraft could fly more direct and efficient routes, minimizing time aloft. That could result in significant operating cost savings to airlines and time savings to passengers. Modern airliners are designed to operate much more efficiently than permitted under current ATM procedures. There are quite differing estimates of the dollar savings, but NASA, for example, estimates savings from using more optimum fuel-burn rates and decreased flight times could be $1.47 billion annually by 2005.

While full implementation of Free Flight is still about 10 years in future, transition to the Free-Flight concept is already underway with efforts like the expanded National Route Program (NRP), a phased approach to eventually allow aircraft flying above 29,000 feet to select their own routes rather than the published preferred IFR routes. As of March 1996, the expanded NRP encompasses all flights above 33,000 feet and flights above 31,000 feet in the Western U.S. Ω

## LOGIC ANALYZER

*(Continued from page 42)*

onto the bottom side of the board next. The cathode lead (marked with a band) is clipped short and surface-mounted to the PC board pad. Be sure the anode lead goes all the way through the board and solder it on both the top and bottom sides of the circuit board.

Bend the leads of pins 2–10 (do not disturb pin 1) of RN2 at the base of the component to form a right angle. Cut the ends of those leads so that you leave a "foot" about 0.1-inch long. Place RN2 onto the bottom side of the board, making sure to push pin 1 through the board. Solder pin 1 on both sides of the board. Solder the remaining pins on the bottom side of the board. Solder a piece of insulated wire where jumper "J" is indicated on Fig. 2B. Be sure that the pad closest to C1 is soldered on both the top and bottom sides of the board.

Solder all the remaining components (except C1 and XTAL1) to the board. Solder C1 into the circuit with the positive lead next to the "+" sign. That lead also needs to be soldered on both sides of the board. Solder XTAL1 onto the board by first laying it in place with its leads facing away from the board. Solder the case of XTAL1 to the board. Place insulation over the bare leads. Solder the leads of XTAL1 to each side of R1.

Remove the outer jacket from both ends of the length of modular telephone cable, leaving 1 inch of insulated wire on one end and 8 inches on the other. Strip ⅛ inch of insulation from all the wires on both ends of the cable. Solder all 6 of the 1-inch long wire ends to the circuit board pads opposite the end of the DB-25 connector. Only the top side of the circuit needs soldering for all wires except ground. The ground lead must be soldered on both sides. Solder the test clips to the other end of the modular cable. Be sure to match the colors of the connectors to the appropriate color designators GRN (Green), BLU(e), YEL(low), RED, and WHT (white) on the PC board.

**Testing.** Download the software application from the **Electronics Now** ftp site (ftp.gernsback.com/pub/EN/logprobe.zip). To run the program, you will need an IBM-compatible 286 or higher running MS-DOS, an EGA or VGA graphics card, 512 Kbytes minimum memory, and one printer port.

Plug the interface into any available printer port. Place a copy of the MS-DOS utilities GRAPHICS.COM and GRAPHICS.PRO in the directory with LOGIC PROBE. Those files might be found in your DOS directory. Type LP to start the program. A blue display with the heading LOGIC PROBE should appear. If that display is not present, check that the graphics card is properly installed. Press any key to continue the program. If the interface is not operating, the error message "Unable to calibrate with no module installed" will appear. Should that happen, carefully look over the top and bottom of the PC board. Check for shorts and unsoldered connections. Also, make sure that all points where the pads need to be connected to both sides of the board are soldered on both top and bottom. This includes the positive lead of C1, the anode of D1, pin 1 of RN2, the GND pad for the probes, and the jumper.

When LOGIC PROBE is able to complete its calibration, the main menu will be displayed. If the time base is correct, the sample rate should be between 0.8 and 7 μs. That sample rate is located in the upper left corner of the main menu.

Verify that all channels are working by testing each channel with a known frequency source that has a 5-volt swing. When testing each channel, ground the unused leads to prevent cross talk on the cable. If the sample-rate error is acceptable (less than 5% or +/− one sample period) and all channels are working, you are ready to familiarize yourself with your new logic analyzer.

**Using The Logic Analyzer.** To learn more about the logic-analyzer software, enter the Help menu by holding down the "Alt" key while pressing the "H" key. Press the enter key to view the help file. Detailed information on using LOGIC PROBE is contained in the help file. Contained in the zip file is a text file named README.TXT. That text file for the most part repeats the contents of the help file, and can be printed out if you find it easier to work with a printed copy. Ω



www.americanradiohistory.com